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Field emissions of NH_3 and NO_x following urea application to wheat

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Abstract

Within the scope of international efforts for air pollution abatement, emissions of N-containing trace gases from sustainable and effective cultivation become of more importance. The objective of this investigation was to determine actual NH_3 and NO_x emissions from surface applied urea fertiliser in field experiments with modified instrumentation based on the dynamic chamber technique. In 1999 and 2000 urea or CAN (calcium-ammonium-nitrate) were supplied to winter wheat in several applications (N application rate: 80 kg N ha^{-1}). Nitrogen emissions were measured continuously for 10 days after each fertilisation. Under weather conditions favouring losses (high temperature and lack of precipitiation) urea application led to NH_3 emissions up to 4.4 kg NH_3-N ha^{-1} or 5.5 % of the applied nitrogen. The NH_3-emissons of CAN reached a maximum of 1.2 kg NH_3-N ha^{-1} or 1.5 % of the applied nitrogen. NO_x emissions were low (up to 140 g NO_x-N ha^{-1} for both fertilisers). The results from this study suggest that the risk of NH_3 losses is significantly smaller under the semi-humid weather conditions of Southern Germany than has previously been assumed.

Introduction

The potential for gaseous N losses from urea fertiliser following surface application has been recognised for many years. With the increasing use of urea as a source of N, all over the world, it is gaining more attention. NH_3- and NO_x-emissions from applied urea, and thus its fertiliser use efficiency, depend on soil characteristics and environmental factors (Rachhpal-Singh, 1987; Vermoesen *et al.*, 1996). The release of NH_3 by hydrolysis of urea is affected by pH, NH_4^+ concentration in the soil solution, soil moisture, soil temperature and soil texture (Fleisher *et al.*, 1987). The most important process related to the production of NO_x in soils can be nitrification as well as the result of denitrification and chemodenitrification (Williams *et al.*, 1992). Although an increase in NO_x emissions with addition of N has been recorded (Galbally, 1989), the effect of fertiliser type on NO_x losses has not been thoroughly investigated (Maggiotto *et al.*, 2000).

The objective of this study was to determine actual NH_3 and NO_x emissions from surface-applied urea and CAN fertiliser in field experiments under the environmental conditions of Southern Germany.

Materials and methods

Site description

The flux measurements were performed on an experimental area of the Chair of Plant Nutrition, TU-Munich in Southern Bavaria, Germany (800 mm annual precipitation, 7.4 °C air temperature), from 25 March to 23 June 1999 and from 22 March to 14 June 2000. The soil is characterised as a silty loam from loess with pH($CaCl_2$) 6.3.

Mineral N-fertiliser were given to winter wheat as granular urea and CAN (calcium-ammonium-nitrate) in several applications to the soil surface (application rate 80 kg N ha^{-1} to unfertilised plots, respectively).

NH_3 and NO_x volatilisation measurements

NH_3 and NO_x emissions were measured with a modified instrumentation based on the dynamic chamber technique. Ambient air was continuously drawn through chambers, (covering ¼ m² soil surface) with a constant flow rate. Sample air was collected and led to the NH_3/NO_x-analyser (CLD700AL + NH_3-Converter, Fa. EcoPhysics, Gürnten, Switzerland) by magnetic valves. NH_3 and NO_x fluxes were calculated from the difference of NH_3 and NO_x concentration in ambient and sample air and from the airflow through the chamber.

To minimise the influence of the artificial climate inside the chambers (higher temperature, drying out of the soil surface) on the volatilisation processes, the chambers were moved to an undisturbed part of the plot up to four times a day dependent on the weather conditions.

Six chambers were used simultaneously to get comparative measurements with different N fertilisers. For ten days after each fertilisation NH_3 and NO_x fluxes were determined.

Additional data of temperature and precipitation were collected from a meteorological station close to the experimental area.

Results and discussion

In both years, significant differences were found between the NH_3 emissions in the single periods (Table 1). Urea led to higher NH_3 emissions (up to 4.4 kg NH_3-N ha^{-1} or 5.5 % of the applied nitrogen) than CAN (up to 1.2 kg N ha^{-1} or 1.2 %). Maximum losses for both fertiliser types were found, when they were applied on 26 April 2000. For the other application dates the losses were less or even NH_3 deposition was found. These results are in contrast to Schulz *et al.* (1999) establishing NH_3 emissions of 23 % (urea) or 11 % (CAN) of the applied N by a micrometeorological technique in fields of Eastern Germany.

Higher NH_3 losses (up to 50 %) than determined in this study were also found in laboratory experiments and under tropical climate in rice culture (Vermoesen *et al.*, 1996; De Datta *et al.*, 1989; Freney *et al.*, 1993).

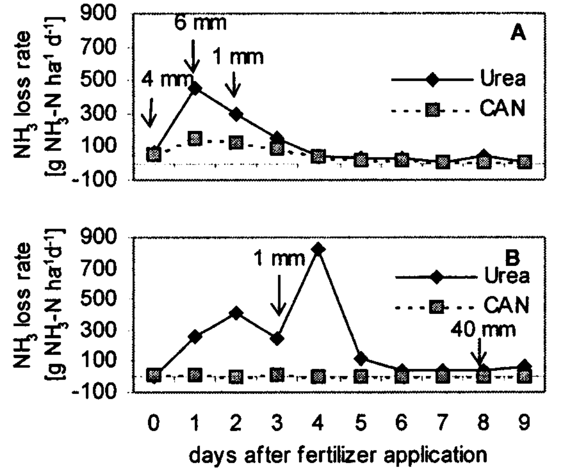

Figure 1. Course of NH_3 emissions as well as occurrence and quantity of rainfall following the fertiliser application in 5 June 2000 (**A**) and 10 May 1999 (**B**).

NH_3-volatilisation was directly influenced by the temperature during the measurement period. In 1999 as well as in 2000 NH_3 losses increased significantly at temperatures higher than 15 °C. Higher temperature lead to enhanced NH_3 losses, because the equilibrium between NH_4^+ and NH_3 in the soil solution shifts to NH_3 and also the velocity of NH_3 volatilisation (Urease activity) increases (Vermoesen *et al.*, 1996).

Thus, this temperature effect is covered by the occurrence, distribution and quantity of rainfall during the first five days of the measurement period. Comparing the course of the NH_3 losses in the measurement periods after 5 June 2000 and 10 May 1999, shows a distinct decrease when rain occurs immediately after the fertilisation (Figure 1A). Late precipitation had no more influence on the total NH_3 losses of the period (Figure 1B). The relation between soil moisture and NH_3 emissions was discussed by Vermoesen *et al.* (1996).

NO_x volatilisation were low (up to 153 g NO_x-N ha^{-1}) for both fertilisers compared to NH_3. A correlation between the environmental conditions and NO_x losses was not found. Urea, as an ammonium-based fertiliser, tended to a smaller release of NO_x than CAN (nitrate-based) in accordance with investigations of Beauchamp (1997) and Maggiotto *et al.* (2000).

The results from this study suggest that the risk of NH_3 and NO_x losses is significantly smaller under the prevailing environmental conditions of Southern Germany than has previously been assumed.

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Table 1. Cumulative NH_3 and NO_x losses, precipitation and temperature within 10 days following surface application of urea and CAN to wheat at several dates.

Date of Fertilisation	NH_3 Emissions Urea		CAN		NO_x Emissions Urea		CAN		Temperature	Precipitation
	%[1]	kg N ha^{-1}	%	kg N ha^{-1}	%	G N ha^{-1}	%	g N ha^{-1}	°C	mm
1999										
25 March	0.6	0.5	<0.1	<0.1	0.1	51	0,1	115	7.7	11.1
06 April	-0.1	>-0.1	<0.1	>-0.1	0.2	153	0,2	130	7.7	26.1
26 April	0,5	0.4	0.1	0.1	0.0	36	0,1	91	13.3	0.5
10 May	2.6	2.0	0.1	0.1	0.1	98	0,1	100	19.1	49.5
17 June	-0.1	>-0.1	-0.1	>-0.1	0.1	46	0,2	139	12.4	22.1
2000										
22 March	0.6	0.5	<0.1	<0.1	>-0.1	-15	0.1	43	5.7	41.7
10 April	0.2	0.1	0.2	0.2	0	-4	>-0.1	-11	8.0	32.3
26 April	5.5	4.4	1.5	1.2	0.1	67	0.1	92	15.4	4.8
05 June	1.4	1.2	0.7	0.5	0.2	144	0.1	52	18.5	9.5

[1] percent of applied N (80 kg N ha^{-1})